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Set Name side by side	Query	Hit Count	Set Name result set
DB=USPT; PLUR=YES; OP=OR			
L32	5805082.pn.	1	L32
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DB=USPT,USOC,EPAB,JPAB,DWPI,TDBD; PLUR=YES; OP=OR			
L28	L27 and medication	1	L28
L27	L26 and pharmacy near system	1	L27
L26	(online or on-line or internet or network or www) near order$	5795	L26
L25	L24 and (formulary or ingredient or medical) near records	24	L25
L24	L23 and database	113	L24
L23	L22 and clients	120	L23
L22	L21 and servers	356	L22
L21	L20 and (networks or www or internet)	4655	L21
L20	(pharmaceutical or pharmacy) and administration	112391	L20
L19	709.clas.	14724	L19
L18	709/224	3854	L18

L17	709/223	3527	L17
L16	709/213	1308	L16
L15	700/231	397	L15
L14	700/90	1017	L14
L13	705/10	1403	L13
L12	705/9	756	L12
L11	705/4	509	L11
L10	705/3	653	L10
L9	705/2	761	L9
L8	705/1	2455	L8
L7	707/104.1	2793	L7
L6	700/231	397	L6
L5	700.clas.	33835	L5
L4	707/100	3593	L4
L3	707.clas.	12514	L3
L2	705.clas.	11196	L2
L1	705/26	2398	L1

END OF SEARCH HISTORY

L25: Entry 22 of 24 File: USPT Dec 31, 1991

US-PAT-NO: 5077666
DOCUMENT-IDENTIFIER: US 5077666 A
**** See image for Certificate of Correction ****

TITLE: Medical information system with automatic updating of task list in response to charting interventions on task list window into an associated form

DATE-ISSUED: December 31, 1991

INVENTOR-INFORMATION:

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ASSIGNEE-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY	TYPE CODE
Emtek Health Care Systems, Inc.	Tempe	AZ			02

DISCLAIMER DATE: 20081210

APPL-NO: 07/ 572317 [PALM]
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PARENT-CASE:
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US-CL-CURRENT: 705/2

FIELD-OF-SEARCH: 364/413.01, 364/413.02, 364/408, 364/401

PRIOR-ART-DISCLOSED:

OTHER PUBLICATIONS

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"William Beaumont Hospital and Its New Generation System", U.S. Healthcare, vol. 6, No. 3, Mar. 1988, Childs.
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Ralph A. Korpman, "Patient Care Information Systems-Looking to the Future", Software in HealthCare, Parts 1-5, Apr./May 1984-Dec./Jan. 1984-1985.

ART-UNIT: 238

PRIMARY-EXAMINER: Hayes; Gail O.

ATTY-AGENT-FIRM: Nielsen; Walter W.

ABSTRACT:

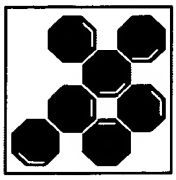
A hospital information system comprises a data processing system including a plurality of terminals having display means and data entry means. Patient information is entered into the system via the terminals, is organized hierarchically in the system, and may be displayed to users having proper access to the system. The system provides a time-oriented task list, which is automatically generated from data which has been entered from physicians' and nursing orders. Tasks may be charted by a system user without exiting from the task list, and all associated form(s) are automatically updated.

3 Claims, 12 Drawing figures

CHECK SAMPLE

American Society of Clinical Pathologists

CLINICAL CHEMISTRY, VOLUME 41, NUMBER 4, 2001, ISSN-1056-599X



Clinical Chemistry No. CC 01-4 (CC-314)

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Learning Outcomes

Upon completion of this exercise, the participant should be able to

- understand the clinical significance of abnormally high or low potassium concentrations in the blood.
- know the commonly used methods for measurement of potassium and their analytic interferences.
- recognize the most frequent artifactual causes of hyperkalemia and hypokalemia.
- suggest alternative methods of specimen collection or analysis to obtain correct measurements of potassium in cases of artifactual elevations.

This CME activity was planned and produced in accordance with the ACCME Essentials. The American Society of Clinical Pathologists is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians. The American Society of Clinical Pathologists designates this educational activity for 1 hour in category 1 credit toward the AMA Physician's Recognition Award.

The author(s) has no financial relationship with any manufacturer or interest in any product discussed in this exercise.

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HISTORY

A 16-year-old boy was admitted to the hospital for treatment of newly diagnosed acute leukemia. Admission laboratory measurements were remarkable for elevated leukocyte count with a predominance of blasts (see **Laboratory Data**). The marked elevations of lactate dehydrogenase and uric acid were consistent with a rapidly growing population of cells. Bone marrow examination revealed extensive replacement with a blast population that contained Auer rods and azurophilic granules. Using flow cytometry, these cells were found positive for CD13, CD34, and HLA-DR, and coexpressed CD7 and CD2, but did not express other lymphoid markers. The diagnosis was acute myelocytic leukemia (FAB M1).

To avoid complications of tumor lysis syndrome and because his uric acid level was already elevated, the patient underwent reduction of circulating leukocytes by cytopheresis on 2 successive days and then began chemotherapy. For extended care, placement of a central line was planned; however, the anesthesiologist deferred the procedure because the patient's potassium measurements had fluctuated from below 4 to more than 10 mEq/L (<4->10 mmol/L) during a 4-day period (**Figure**). The laboratory called all critical values of potassium (>6.1 mEq/L) immediately to the patient's medical team. Because the patient showed no signs of hyperkalemia, the initial clinical interpretation was artifactual elevation. These measurements had been performed on serum or heparinized plasma specimens using three different Vitros 950 chemistry analyzers (Ortho-Clinical Diagnostics, Rochester, NY) all of whose quality control had been stable. The patient's electrocardiogram suggested hypokalemia, and whole blood specimens tested with an ion-selective electrode in a satellite blood gas laboratory repeatedly showed potassium concentrations in the low normal range (<4 mEq/L). Because of confusion regarding the patient's true potassium level, the attending oncologist called the laboratory director for consultation.

Questions to be considered:

1. What organ systems are affected by alterations in plasma potassium concentration, and what is the clinical significance of panic values of potassium?
2. How is potassium measured in the clinical laboratory?
3. What types of specimens are appropriate for quantitation of potassium and other electrolytes?
4. How are potassium concentrations affected by preanalytic factors such as hemolysis, thrombocythemia, leukocytosis, and prolonged storage?

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Admission Laboratory Results.

Test	Patient Result	Reference Range
Sodium, mEq/L (mmol/L)	143 (143)	135-145 (135-145)
Potassium, mEq/L (mmol/L)	3.6 (3.6)	3.6-5.1 (3.6-5.1)
Chloride, mEq/L (mmol/L)	102 (102)	101-111 (101-111)
Bicarbonate, mEq/L (mmol/L)	27 (27)	21-31 (21-31)
Glucose, mg/dL (mmol/L)	100 (5.5)	65-110 (3.6-6.1)
Urea nitrogen, mg/dL (mmol/L)	5 (1.7)	6-22 (2.1-7.8)
Creatinine, mg/dL (μmol/L)	0.9 (79.5)	0.7-1.4 (61.8-123.7)
Uric acid, mg/dL (mmol/L)	11.1 (0.66)	4.0-8.4 (0.24-0.49)
Aspartate aminotransferase, U/L	73	0-50
Alanine aminotransferase, U/L	96	0-75
Alkaline phosphatase, U/L	133	50-350
Lactate dehydrogenase, U/L	1415	0-400
Total bilirubin, mg/dL (mmol/L)	0.7 (11.9)	0.2-1.3 (3.4-22.2)
Total protein, g/dL (g/L)	7.7 (77)	6.0-8.0 (60-80)
Albumin, g/dL (g/L)	4.2 (42)	3.7-4.9 (37-49)
Calcium, mg/dL (mmol/L)	9.0 (2.25)	9.2-10.7 (2.3-2.6)
Hemoglobin, g/dL (g/L)	7.7 (77)	13.1-16.4 (131-164)
Hematocrit, %	25.7 (0.26)	38.0-48.5 (0.38-0.48)
Platelet count, $\times 10^3$/mL ($\times 10^9$/L)	99 (99)	165-350 (165-350)
Leukocytes, $\times 10^3$/mL ($\times 10^9$/L)	386.0 (386.0)	3.2-11.0
Differential:		
Segmented neutrophils	1%	
Lymphocytes	6%	
Monocytes	2%	
Blasts	91%	

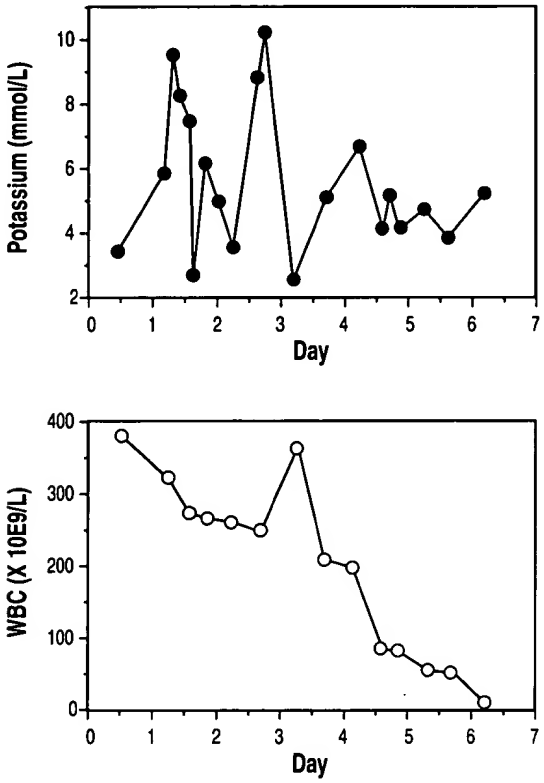

Figure. Serial measurements of potassium and WBC count in the patient from presentation through initial stages of chemotherapy.

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PSEUDOHYPERKALEMIA IN ACUTE MYELOCYTIC LEUKEMIA

Chemistry and Physiologic Role of Potassium

Potassium (K) is element number 19 with an atomic weight of 39. It is larger than sodium (Na, element number 11); both sodium and potassium form monovalent cations (that is, they carry a single positive charge) that are freely soluble in water. Potassium is present in the body primarily intracellularly with only about 2% being extracellular. Normal physiologic concentrations of potassium in plasma are in the range of 3.5 to 5.0 mEq/L (3.5–5 mmol/L). In serum specimens of healthy individuals, the concentration of potassium is generally 0.1 to 0.2 mEq/L (0.1–0.2 mmol/L) greater than in their plasma specimens, because of the release of intracellular potassium stores from platelets on clot formation.

The relative distribution of potassium between intracellular and extracellular fluids is the major determinant of the electric potential across cell membranes. Depolarization of the cell membrane potential is fundamental for nerve cells to conduct impulses and for muscles (both skeletal and myocardial) to initiate contraction. Accordingly, disturbances in potassium content of the body and the relative amounts in body fluids compared with those seen within cells can strongly affect neuromuscular and cardiac functions.

Excess potassium can be removed from the blood by uptake into the large intracellular reservoir of muscle or by elimination into the urine. Potassium freely enters the glomerular filtrate, from which most of it is reabsorbed in the proximal tubule and loop of Henle; some of it is then secreted in the distal tubule, which is the main mechanism for renal elimination of potassium. High concentrations of aldosterone stimulate net excretion of potassium through enhanced secretion. When aldosterone is deficient, potassium tends to be conserved. Further modulation of potassium excretion is influenced by acid-base status, sodium delivery to the nephron, and rate of urine flow through the distal nephron. Therapy with loop diuretics favors increased excretion of potassium, which is a frequent reason for measurements of serum potassium to initiate correction. Renal diseases likewise affect potassium concentrations. In patients receiving acute care for cardiac, pulmonary, renal, and other organ abnormalities, monitoring and adjustment of circulating potassium concentrations is a standard clinical practice.

Measurement of Potassium

Flame Photometry

When excited in a flame of propane burning in air, the monovalent cations sodium, potassium, lithium, and cesium emit light at wavelengths 589, 768, 671, and 852 nm, respectively.[1] The intensity of light emitted is proportional to the concentration of the ion at each wave-

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length. Usually a sample for analysis of sodium or potassium is diluted (typically 100 to 200 fold) with a solution containing a known concentration of lithium or cesium to serve as an internal standard to correct for fluctuations in flame intensity. Interference filters selectively pass light at the wavelengths of interest, which are then monitored by photodetector for quantitation against calibrators of known concentration of sodium or potassium.

Flame photometry is highly specific for the ion being measured because of the sharpness of each distinct emission wavelength. But this method suffers from spuriously low measurements of sodium and potassium in serum specimens that have high concentrations of lipids or protein (as in myeloma).[2] Flame photometry actually measures molar ion concentration (ie, moles per liter of solution) in the sample, which is diluted for presentation to the flame. Whenever the water content of plasma is reduced, the content of water-soluble ions is reduced proportionately, although their actual ionic activities (which are physiologically important) may be completely normal. The ionic activity is related to molal concentration (ie, moles per kilogram of solvent). The difference in measurements between molar and molal concentrations is termed "the solvent exclusion error." Whenever a substance such as lipid or protein excludes solvent from a solution, the molar concentration of a solute such as potassium is lower than its molal concentration.

Flame photometry requires dedicated instrumentation, potentially explosive tanks of propane gas, and substantial set-up time prior to analysis.

The principle for measurement by an ion-selective electrode (ISE) is potentiometry, in which an electrical potential develops across a membrane because of a difference in the concentration of a particular ion.

Ion-Selective Electrodes

The principle for measurement by an ion-selective electrode (ISE) is potentiometry, in which an electrical potential develops across a membrane because of a difference in the concentration of a particular ion.[1] The relationship between the concentrations of the ion on either side of the membrane (I_1 and I_2) and the electrical potential (E) is described by the Nernst equation:

$$E = -\frac{R \times T}{z \times F} \times In \frac{I_1}{I_2}$$

where R is the gas constant (8.31431 Joule/K × mol),
z is the charge on the ion,
T is the absolute temperature (K, Kelvin),
F is the Faraday constant (96487 Coulomb/mol), and
In is the natural logarithm.

Specificity of measurement is established by the selective permeability of the membrane to individual ions. ISEs for sodium may use glass membranes constituted to be highly permeable to sodium but not to

other ions. ISEs for measurement of potassium can be made with the antibiotic valinomycin, which has a ring of oxygen atoms that form a pore that is highly selective for potassium ions. The Synchron chemistry systems of Beckman-Coulter (Brea, Calif) use ISEs to measure ion activities in diluted samples of serum. In contrast, instruments from NOVA Biomedical (Newton, Mass) and from AVL Scientific (Roswell, Ga) can measure ion activities directly on undiluted whole blood specimens. The ISEs on the Vitros analyzers (as in this case) are thin-film devices intended for single use on undiluted serum or plasma. Methods that utilize measurement on diluted samples (indirect potentiometry) are also subject to solvent exclusion error, whereas those that measure ion activities directly on undiluted samples are not affected by it.

Enzyme Activation

Although this principle of measurement is not currently in common use, it may become much more so in the future because it simplifies the processes on automated instruments by eliminating the need for ISEs and potentiometry. Instead it employs the same spectrophotometric detection steps that are already in use for measuring many enzyme activities in serum specimens.[3] In essence the potassium ion activity in a sample is used to enhance specific enzyme-catalyzed reactions that can be linked to change in concentration of a substance that is readily detected by spectrophotometry (eg, reduced form of nicotinamide adenine dinucleotide). Unless special steps are taken to avoid it, these methods may also be subject to solvent exclusion error.

Abnormalities of Potassium Concentration

Because of the key role that potassium plays in the excitability of nerve and muscle cells, abnormalities in its concentration are frequently crucial in the health of patients.[4] Consequently, rapid determination of potassium levels is frequently necessary for correction of cardiac arrhythmias. Detecting both very high (hyperkalemia) and very low (hypokalemia) levels of potassium can be critically important for patient care. Such abnormalities are generally considered "panic values" to be reported immediately to the physician because of their potentially life-threatening implication.

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Hypokalemia

Low potassium levels (especially <3.0 mmol/L) may induce premature atrial and ventricular contractions or tachyarrhythmias as well as atrioventricular block. Hypokalemia generally reflects total body depletion of potassium, which may arise because of gastrointestinal loss (eg, chronic diarrhea) or renal loss (eg, diuretic therapy or various congenital and acquired renal tubular defects). It is particularly important to avoid this condition in patients receiving digoxin because of the enhanced car-

diac excitability from the combination of that drug with low potassium. Treatment of hypokalemia consists of replacement with potassium chloride either orally or intravenously.

In diabetic ketoacidosis, typically a potassium deficit must be corrected during administration of insulin to normalize glucose concentrations. Hypokalemia may also occur when potassium is taken up intracellularly, such as with total parenteral nutrition in which carbohydrate feeding shifts potassium into cells along with glucose. A similar effect may occur in vitro with extremely elevated leukocyte count in myeloid leukemias: pseudohypokalemia can evolve in such unseparated blood specimens because of uptake by the leukocytes as they stand around at room temperature (see below). True hypokalemia because of renal loss is common in patients with leukemia even before medical treatment,[5] perhaps because of reninlike mediators elaborated by blast cells.[6]

Pseudohypokalemia can evolve in such unseparated blood specimens because of uptake by the leukocytes as they stand around at room temperature.

Hyperkalemia

High potassium levels (>5.5 mmol/L) can lead to flaccid paralysis of skeletal muscle followed by cardiac nodal and ventricular arrhythmias in which the Q-, R-, S-wave complex widens, the PR interval prolongs, and with progressively increasing hyperkalemia (>6.5 mmol/L), ventricular asystole occurs.

Hyperkalemia can be caused by decreased excretion of potassium by the kidneys, especially if it persists over time; it can also be exacerbated by administration of potassium during renal failure. More acutely, hyperkalemia can be caused by acidosis that stimulates potassium to move out of cells or by other conditions associated with cell damage and release of intracellular contents such as intravascular hemolysis, rhabdomyolysis, and tumor lysis syndrome. Other causes of hyperkalemia in patients with leukemia can include adrenocortical insufficiency,[7] splenic irradiation,[8] trimethoprim-sulfamethoxazole,[9] cyclosporine use in bone marrow transplant,[10] and succinylocholine administration for mechanical ventilation.[11]

Artifactual Elevations of Potassium

Unfortunately there are several factors that may give rise to artifactual elevations of potassium in blood specimens (**Table**). Proper clinical management requires that the physician recognize these artifacts and discriminate them from true episodes of hyperkalemia.

In Vitro Hemolysis

The performance of phlebotomy with hard metallic or glass surfaces and vacuum pressures frequently results in immediate lysis of some erythrocytes in a specimen.[12] When the bore of a needle (calibrated according to gauge, where larger numbers represent smaller bores) has a very

When the bore of a needle (calibrated according to gauge, where larger numbers represent smaller bores) has a very small cross-sectional area, rapid movement of blood under pressure creates sheer forces on the erythrocytes that causes some to break open.

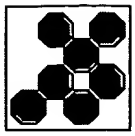


Table. Causes of Pseudohyperkalemia

In vitro hemolysis
– Traumatic phlebotomy
– Needle gauge
– Flow rates/vacuum
Elevated platelet count
Elevated leukocyte count
Contamination with intravenous fluids
Contamination with anticoagulant (eg, potassium ethelyenediaminetetraacetic acid)
Release from erythrocytes in aged specimen
– Serum sitting on clot
– Respun serum separator tube

small cross-sectional area, rapid movement of blood under pressure creates sheer forces on the erythrocytes that causes some to break open. Specimen collection through a thin "butterfly needle" with its long connecting line into a syringe is also susceptible to hemolysis if undue pressure is exerted when pulling back the plunger. Of course, a skillful phlebotomist should be able to avoid hemolysis by using gentle pressure.

A completely different effect leading to hemolysis can occur with very large bore needles such as with intravenous catheters (eg, 14 gauge). This circumstance often happens when patients in emergency departments have intravenous lines initially placed on arrival. Baseline blood specimens may be obtained (common practice is to collect a "rainbow" assortment of different tube types to meet the requirements for most types of common laboratory tests that could be ordered as medical evaluation proceeds) by putting vacuum collection tubes directly onto the large-bore catheter. Extremely rapid and free flow of blood through large bore tubing into a vacuum also creates hemolysis by turbulence forces. This effect may be even more pronounced in patients whose erythrocytes have already been sensitized because of physiologic responses to trauma such as vasoconstriction secondary to shock.

Extremely rapid and free flow of blood through large bore tubing into a vacuum also creates hemolysis by turbulence forces.

If the specimen is collected into a syringe, the phlebotomist has at least one more opportunity to hemolyze it by jabbing the needle on the syringe through the rubber stopper in a vacuum collection tube and allowing the blood to run through it once more without control over flow rate. This common practice should be avoided because of the risk for needle-stick injury and the potential for hemolysis. One traditional approach that minimizes hemolysis is to remove the needle and gently force the blood from a syringe into collection tubes after removing the rubber tops, replacing the tops when the tubes are full. This procedure should no longer be considered safe practice because it involves excess manipulation of a contaminated needle. As safer needles, such as self-

capping ones, are more widely used, opportunities for misuse in this manner may decrease.

As a result of hemolysis, hemoglobin, potassium, and intracellular enzymes such as lactate dehydrogenase and aspartate aminotransferase are released into the plasma or serum. Inappropriate therapy may be instituted if the physician does not realize that a patient has a normal potassium level despite the laboratory finding of high potassium level in a hemolyzed specimen. Similarly, it is inappropriate to miss hypokalemia in a patient simply because the potassium level was brought up to normal in a hemolyzed specimen.

A hemolyzed specimen usually appears completely normal to the person collecting it, and the hemolysis is typically not discovered until the specimen has been centrifuged and the serum or plasma specimen is examined visually in the laboratory.

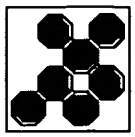
A hemolyzed specimen usually appears completely normal to the person collecting it, and the hemolysis is typically not discovered until the specimen has been centrifuged and the serum or plasma specimen is examined visually in the laboratory. Because hemolysis caused by the mechanical effects of phlebotomy affects only a small number of cells, whole blood specimens for CBC counts can be relatively unchanged. Therefore, substantial hemolysis that is observed in a clinical chemistry or coagulation laboratory, which prompts specimen rejection or request for a redraw, will probably not even be noticed by a hematology laboratory. Consequently, medical personnel who have collected both chemistry and hematology specimens at the same time from a patient can be very confused when the chemistry laboratory reports unacceptable hemolysis while the hematology laboratory makes no such comment.

This situation is not uncommon and may lead to the unfounded suspicion on the part of the specimen collectors that the chemistry laboratory is doing something inappropriate to cause hemolysis whereas the hematology laboratory is operating correctly. This misconception may be further exacerbated if hemolyzed (unrecognized) specimens are also sent to another testing area that performs electrolyte measurements on whole blood specimens; the hemolysis will go unobserved visually on the whole blood specimen, but should be suspected by the astute operator based on inappropriately elevated concentration of potassium.

Release of Potassium from Stored Erythrocytes

When blood specimens are stored before centrifugation, erythrocytes in clot tubes or anticoagulated tubes gradually lose potassium into the surrounding serum or plasma.

When blood specimens are stored before centrifugation, erythrocytes in clot tubes or anticoagulated tubes gradually lose potassium into the surrounding serum or plasma. The adenosine triphosphate–dependent membrane pump that maintains high intracellular concentrations of potassium continues to operate; however, it is less effective at lower temperatures. Accordingly at 4°C the potassium concentration rises more rapidly than at 25°C (room temperature), although the total increase may be only a few tenths of a millimole per liter in 2 to 3 hours.[13] For hospital environments, this time-dependent elevation of serum potassium is rarely significant because specimens are rapidly



transported to the laboratory where they are centrifuged and the serum or plasma can be separated from cells.

Most laboratories use serum separator collection tubes with a gel that forms a barrier between the clot and the overlying serum on centrifugation. The gel barrier prevents any fluid exchange across it, and so the serum can be sampled from the original tube and even stored in it for days to perform additional tests. Our laboratory found an unexpected cause of pseudohyperkalemia from the use of serum separator tubes in an outpatient clinic, which used a centrifuge to process specimens before sending them to the main laboratory for testing. On arrival at the main laboratory, the specimens were respun along with other previously unspun ones. The second spin apparently forced more fluid from around the clot past the gel barrier into the serum layer. This additional fluid was rich with potassium released from the stored erythrocytes, and it led to false elevation of potassium in the serum. This effect may prove problematic in future laboratory automation systems that automatically centrifuge and transport specimens to analyzers without direct operator interaction unless prespun tubes can be identified and treated differently.[14]

Elevated Platelet Count

Platelets normally release their intracellular contents during clot formation. The slight increment (about 0.1–0.2 mmol/L) of potassium in serum specimens compared with plasma specimens from the same patient is generally ignored because it rarely poses an issue for interpretation even if serial measurements are performed on serum specimens from clot tubes alternating with plasma specimens from heparinized tubes. However, as the platelet count rises, the fraction of serum potassium contributed by platelets can readily go beyond 1.0 mEq/L (1.0 mmol/L).[15] A general rule is to expect an increment in potassium of about 0.15 mEq/L (0.15 mmol/L) for every 100 $\times 10^9$ cells/L increase in platelet count.[16] Accordingly patients with thrombocytosis should have their potassium levels monitored strictly with plasma specimens or an alternative method such as ISE on whole blood specimens.

A general rule is to expect an increment in potassium of about 0.15 mEq/L (0.15 mmol/L) for every 100 $\times 10^9$ cells/L increase in platelet count.

Elevated Leukocyte Count

As seen in this patient, extreme elevations of leukocytes in leukemia are associated with spurious increases of serum or plasma levels of potassium.[17,18] Apparently these fragile leukoblasts are highly susceptible to the mechanical forces of phlebotomy, and may become even more sensitive with chemotherapy. This effect on leukocytes may also be accentuated by the practice of collecting a single large syringe of blood, which is then dispensed into individual vacuum tubes by piercing the rubber tops to let the blood drain in. Thus green top tubes (heparin anticoagulant) and clot tubes could both show pseudohyperkalemia because

Extreme elevations of leukocytes in leukemia are associated with spurious increases of serum or plasma levels of potassium.

of leukocytosis, whereas another specimen collected in parallel in a syringe that was directly analyzed in a blood gas instrument could show normal potassium.

A different effect of leukocytosis on potassium may be observed when the cells remain intact. In this situation, the leukocytes may take up potassium along with glucose during the first hour, thereby producing pseudohypokalemia. Once glucose in the specimen is depleted, potassium leakage occurs, resulting in an overall biphasic pattern in the concentration of potassium in plasma or serum.[19]

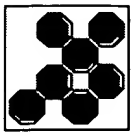
Contamination With Intravenous Fluids

Patients often have intravenous lines placed in the dorsum of the hand. Phlebotomy is usually done through antecubital veins that drain from the hand. If blood specimens are drawn from the same arm that has an intravenous line, it is almost certain to be admixed with intravenous fluids unless special precautions are taken. Common intravenous fluids are normal saline (which tends to elevate sodium and chloride levels proportionately while diluting out all other analytes in serum) or glucose (5% dextrose in water, D5W, which grossly elevates serum glucose when mixed with blood). If the intravenous fluid has other constituents such as potassium chloride, then apparent hyperkalemia may arise in a contaminated blood specimen.

Common sense dictates that blood specimens be drawn from the arm opposite to the intravenous site; however, circumstances such as poor venous access, intravenous lines in both arms, or even amputation may force the phlebotomist to draw a specimen from the same arm. In that case, it is acceptable to draw from the antecubital vein after stopping the intravenous flow and elevating the arm for 5 minutes to clear the intravenous fluids. Immediately after blood collection, the intravenous line may be started again.

Contamination With Anticoagulant

Lavender top specimen collection tubes that are used for CBC counts contain potassium ethylenediaminetetraacetic acid (K_3EDTA) as anticoagulant to chelate calcium. The concentration of potassium in a plasma specimen in a lavender top tube exceeds 15.0 mmol/L, obviously making it unsuitable for electrolyte measurements. Blue top tubes for coagulation studies contain sodium citrate as anticoagulant, which also makes such plasma unsuitable for electrolyte analyses. Green top tubes with heparin (bound with sodium, lithium, or ammonium) do not interfere with electrolyte measurements but are not acceptable for complete blood counts or coagulation testing. A universal anticoagulant is envisioned that will not interfere with chemical analyses, but will preserve cellular morphologies for the complete blood count and maintain the function of coagulation factors.[20] Although a universal anticoagulant is still elusive,



it would theoretically allow a single type of collection tube to be used for virtually all laboratory procedures.

Current recommendations are to collect vacuum tubes in a prescribed order to prevent cross-contamination with anticoagulant between tubes as they are exchanged on the hub of the needle. The order is from first to last: clot tube, blue top tube (sodium citrate), green top tube (heparin), lavender top tube (K_3EDTA), and gray top tube (sodium fluoride and potassium oxalate). This order of draw has been set to minimize any contaminating effects. If a different order is followed, drawing a tube with K_3EDTA before a clot tube could conceivably transfer a small volume of the anticoagulant with a high concentration of potassium to the clot tube, resulting in false elevation.

Case Summary

This patient with acute myelocytic leukemia intermittently demonstrated pseudohyperkalemia. The conditions of phlebotomy apparently caused varying degrees of lysis of circulating myeloblasts, which were present in very high numbers. His true potassium level was determined using gentler means of sample collection; whole blood measurement also verified the low normal levels obtained with some plasma and serum samples. When the patient's leukocyte count fell during chemotherapy, his potassium measurements stabilized without further artifact. He subsequently received transplantation of hematopoietic precursor cells (stem cells) harvested from the peripheral blood of a sibling and is doing well at the time of this writing.

Chemotherapy may have contributed to lysis of the patient's myeloblasts; however, high potassium levels occurred both before and during initial chemotherapy, and some low levels occurred during the chemotherapy when the patient's WBC count was still very high. Therefore, it is reasonable to conclude that the elevations in this patient's potassium level were attributable to variations in phlebotomy technique.

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CME DOCUMENTATION QUESTIONS

15. A patient with a very high number of circulating myeloblasts also demonstrates a very high concentration of potassium in a serum specimen. What should be done next?
    A) Repeat the WBC test using a different anticoagulant
    B) Immediately treat for hyperkalemia
    C) Repeat the potassium measurement on a specimen collected very gently and separated from the cells by centrifugation as soon as possible after collection
    D) Evaluate the patient for hyperlipidemia
    E) Check for diuretic overdose

16. Analytic measurement of potassium in a whole blood specimen using an ion-selective electrode is
    A) sensitive to interference from myeloma proteins.
    B) generally free of interference from myeloma proteins.
    C) the same as with flame photometry.
    D) affected by the hematocrit count.
    E) independent of temperature.

17. Fluctuations in the concentration of potassium in blood are most significant for the direct effect they may have on the
    A) heart.
    B) kidneys.
    C) adrenal glands.
    D) erythrocytes.
    E) leukocytes.

18. A patient comes to the emergency department with lower right abdominal pain of 6 hours' duration. The initial clinical impression is acute appendicitis. An intravenous line is placed, and baseline blood specimens are collected before fluids are administered. The laboratory receives a serum separator clot tube that yields red serum. The potassium concentration in the serum is 6.5 mEq/L (6.5 mmol/L). What is the most likely explanation?
    A) Contamination of the collection tube with hypertonic anticoagulant
    B) Thrombocytopenia
    C) Acute leukemia with excess myeloblasts
    D) In vitro hemolysis through the needle
    E) Laboratory accident during centrifugation

19. Using flame photometry, potassium levels in serum specimens that are higher than expected clinically may be interpreted as
    A) positive interference from sodium.
    B) negative interference from sodium.
    C) positive interference from lithium.
    D) positive interference from cesium.
    E) true potassium.

Note: If you wish to receive CME credit, enter the answers to these test questions on your 2001 Check Sample Program Answer Sheet. Retain your answer sheet until the final exercise for this series has been distributed (there are 8 exercises in the Clinical Chemistry series). DO NOT SEND THE ANSWERS TO THE ASCP AT THIS TIME.